

capital," and so forth. If that interpretation is correct, then there has been no such drought in South Africa in the years stated.

This is proved by the accompanying table. It shows the average rainfall over each of the twenty rainfall districts of South Africa, during each year, in percentages of the means. These means have been computed for 160 stations having long records of twenty years, more or less, and are fully given and explained in my "Introduction to the Study of South African Rainfall." The information from which they are derived is open to all who take the trouble to look for it in the annual reports of the Cape Meteorological Commission.

The great mortality among cattle and stock can be explained without assuming that there has been a prolonged drought. In farming matters we live from hand to mouth. Farmers of the Karroo prefer to pray for rain rather than take the trouble to store it up when it comes. Therefore, if the rain is short in the late summer, and late in coming in the next spring, they have no reserve to fall back upon, and their cattle die. One year's drought kills off the stock almost as surely as fifty years' would. For instance, there was great loss of stock in 1897. Yet what were the facts of rainfall? At my station, where the annual mean is about 18.5 inches, the fall in December, 1896, was 8.42 inches; in the whole of 1897 it was 8.85 inches, and in January,

Percentages of Rainfall in the Various Districts of South Africa during the Years 1891 to 1902.

Sections	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
I. Cape Peninsula	101	135	87	82	92	80	97	118	106	86	98	142
II. South-West	85	137	107	93	105	69	89	117	110	106	108	149
III. West Coast	97	139	103	94	86	57	84	122	128	122	99	122
IV. South Coast, W.	104	131	104	95	82	100	81	80	68	105	116	142
" " E.	133	112	116	89	88	104	111	95	64	87	103	125
V. Southern Karroo, W.	98	104	(105)	110	78	99	80	79	80	118	123	144
" " E.	138	103	116	85	74	101	86	65	55	93	104	130
VI. West-Central Karroo, W.	73	122	92	94	87	72	92	84	66	125	123	128
VI. West-Central Karroo, E.	135	112	114	147	98	101	82	86	87	131	93	87
VII. East-Central Karroo	134	97	115	99	95	97	74	91	64	105	103	97
VIII. Northern Karroo, W.	111	91	121	123	92	81	60	88	116	135	107	66
" " E.	163	107	111	110	102	98	55	104	95	97	105	82
IX. "Northern" Border, W.	130	104	97	153	83	83	43	78	173	132	95	53
" " E.	162	93	99	155	97	83	51	105	106	89	111	94
X. South-East	138	103	127	93	94	103	83	95	75	82	92	96
XI. North-East	162	112	128	99	94	105	55	110	98	88	97	82
XII. Kaffraria	136	108	150	98	99	107	80	107	72	69	91	94
XIII. Basutoland	125	104	127	92	104	106	68	107	98	83	105	101
XIV. Orange River Colony	143	111	108	101	108	83	70	105	104	94	92	87
XV. Natal	114	96	153	98	120	107	90	119	87	74	112	97
<i>Summary—</i>												
Area of Winter Rains... ..	94	137	99	90	94	69	90	119	115	105	102	138
" Spring and Autumn Rains	109	114	107	95	82	95	90	81	67	106	114	134
" Summer Rains	138	103	121	114	99	96	68	100	98	98	100	86
South Africa	124	111	114	105	94	92	77	98	93	101	104	106

It is pretty plain that the area of winter rains, including the west coast and Cape Peninsula, was short of rain in 1896; that 1897 was a dry year over the area of summer rains, which comprises the greater part of South Africa; and that the south coast and adjacent districts, where the rainfall is fairly uniform throughout the year, had a dry year in 1899, and one not very wet in 1895. The area of summer rains, being so much greater than the rest, of course sets the tone of the mean rainfall of the whole country, making 1897 a dry year on the whole, and 1891 a very wet year.

There seem to be dry areas somewhere or other in pretty well every year. For example, the rainfall was short in the western part of the area of summer rains in 1902, although the fall was good enough further east. It was short over the east-central Karroo and south-east in 1899 in sympathy with the dryness of the south in that year. Even in 1891 there was a short fall over an extensive region.

I fancy that the impression of unusual dryness over South Africa in recent years arises from the misleading mean values used by the Meteorological Commission for comparative purposes. These are taken from Buchan's rather futile "Rainfall of South Africa," and average fully two inches (equal to perhaps 10 per cent.) too great. Buchan used only the rainfall of the ten years 1885-94 in constructing his results, and therefore got inflated averages in consequence of the heavy rainfall of 1891; whence the rainfalls of recent years are made to appear *minus* as compared with what is called the mean, whereas, as compared with the better means of longer periods, they would be often *plus*.

1898, it was 8.43 inches. Thus there was a drought during 1897, many cattle died, and there was much praying for rain. The year 1903 was probably almost the same as 1897, the fall at Kimberley being only some 65 per cent. of the mean, whereas the fall during the last half of 1902 was good, and during the first half of 1904 excellent. But with the exception of these years there has been nothing that can properly be called drought, in the sense of Sir J. Eliot's address, over any extended region of South Africa within the past fifteen years at least. Thus there is nothing to justify the statement that we have been under the same influence as that which set up the prolonged drought in Australia and the dry years in India. J. R. SUTTON.

I TRUST to your courtesy to give my reply to Mr. Sutton's criticisms on certain portions of my address at the recent British Association meeting.

My address was in part based on an investigation I have had on hand for nearly two years, and which will be shortly published as a paper in the *Indian Meteorological Memoirs*. In that will be found a statement of the chief features of the meteorology of South Africa during the period 1892-1902. It is confessedly based upon very imperfect information—partly derived from newspaper reports, partly from data in certain meteorological reports received from Cape Town by the Calcutta Meteorological Office, and partly from data obtained from Mr. Hutchins, Conservator of Forests, Cape Colony, with whom I have been in correspondence for many years on the meteorology of South Africa and

its relation to that of India. Mr. Hutchins was for some years in the Madras Forest Department before he went to the Cape some fifteen or twenty years ago. He has made a special study of the rainfall of South Africa, and is a careful and enthusiastic investigator in rainfall problems. He is, from his double experience in India and South Africa and his present official work and position, eminently qualified to form a judgment on the abnormal features of rainfall distribution in either area, and on their economic effect. It is hence, as I hope to show later, very satisfactory that Mr. Sutton's figures confirm the general inferences I made about South African rainfall, based chiefly on Mr. Hutchins's information, in my address.

Before discussing Mr. Sutton's data and inferences, perhaps I may be permitted to deal with two or three important issues raised in Mr. Sutton's letter.

The first is contained in the opening paragraph, in which he says "south-east winds are rare on the south-east coast of South Africa, and the rain of the greater part of the tableland and north-east coast comes mostly from some northerly direction." If these casual remarks have any point at all, I think I am correct in assuming that they imply that Mr. Sutton considers the rainfall in the areas mentioned is not due to humid currents from the Indian Ocean, but from the dry interior to the north of the tableland. I have examined the rainfall charts of South Africa given in Bartholomew's "Meteorological Atlas," and they certainly indicate to me that the aqueous vapour, the condensation of which gives rainfall in the eastern half of South Africa, is brought up by air movement from the Indian Ocean, and occurs as a summer precipitation. Hence, so far as I can reasonably judge, that area forms a part of what I have termed the Indo-oceanic region. I might add, in further reply, that rain in certain parts of India during the south-west monsoon chiefly occurs with easterly and north-easterly, and even with northerly winds. But these facts have not yet been utilised by anyone to prove that the rainfall is not brought up from the adjacent seas and oceans by the south-west monsoon circulation.

Mr. Sutton in a later paragraph says he fancies that "the impression of unusual dryness over South Africa in recent years arises from the misleading mean values used by the Meteorological Commission for comparative purposes which are taken from Buchan's rather futile 'Rainfall of South Africa,' and average fully two inches (equal to perhaps 10 per cent.) too great." There is an air of certainty about this statement which I am unable to share without further proof. Buchan's means are based on ten years' data, Mr. Sutton's on twenty years' data. It does not necessarily follow that twenty years' means are better representatives of normal or average conditions than ten years' means. It depends entirely upon whether the ten years may or may not be accepted as representing the normal conditions, and whether the additional ten years' data are for an abnormal period or not. The fact that the two sets of means differ on the average of the whole area by 10 per cent. indicates to an outsider on South African meteorology like myself that it is quite as probable the ten years' additional data erred in defect as that the ten years' data employed by Dr. Buchan erred in excess. There hence appears to be (in the absence of any proof) an element of doubt in his means, just as he asserts to be the case in the "rather futile" means of Dr. Buchan.

Again, if I read Mr. Sutton's letter rightly, he considers that the question as to whether the crops have failed over large areas being due to drought is settled by a consideration of percentage variations. It is certainly not the case in India. A percentage variation gives no certain indication unless considered in relation to the normal fall, and also to its time-distribution. A deficiency of 25 per cent. is of absolutely no economic importance in such areas as Sind (with an average rainfall of about four inches) or such as Arakan (with an average of more than 200 inches). The former area depends solely on irrigation for cultivation, and the latter is so abundantly supplied for the rice crop that it bears a loss of fifty inches lightly. On the other hand, in the regions termed the dry zones in India, where the mean rainfall ranges between fifteen inches and thirty inches, a deficiency of 20 per cent. is usually a serious matter, more especially if it accompanies more irregular distribution than

usual unsuited to the staple crops. Local knowledge of the agricultural and economic conditions is hence of the greatest importance in estimating the probable effect of a given variation of rainfall in any area. Mr. Hutchins, I have every reason to suppose, possesses such knowledge for South Africa, and hence I attach the highest value to his information on such matters.

The evidence I have collected, a small portion of which was given in my address, appears to me to have established that during the period 1895-1902 there was a marked tendency to more or less continuous deficiency of rainfall over the Indo-oceanic area, most pronounced in dry inland districts, and which in India intensified into severe droughts in the years 1896, 1899, and 1901, diminishing the crop returns over large areas to such an extent that it was necessary to resort to famine relief on a large scale during the twelve months succeeding each period of crop failure.

I was unable to make as precise statements for either Australia or South Africa, but the scanty facts and information at my disposal appeared to justify the statement that these areas were similarly affected. I also pointed out that this period stood in marked contrast to a preceding period of three years, 1892-4, when the precipitation was apparently in general excess over the same large area.

I give in the following table a comparison between the rainfall variations of India, and the area of spring, summer, and autumn rains in South Africa, which, so far as I can judge, is mainly dependent on the Indian Ocean supplies of aqueous vapour. I give, in the absence of the number of stations for each area, the arithmetic means of the second and third horizontal rows of figures in Mr. Sutton's summary of his data:—

Period of general excess of rain				Period of general deficiency of rain			
Year	Percentage variation			Year	Percentage variation		
	India	S. Africa			India	S. Africa	
1892 ...	+12	...	+ 8	1895 ...	- 5	...	- 9
1893 ...	+22	...	+14	1896 ...	-12	...	- 5
1894 ...	+16	...	+ 4	1897 ...	normal	...	-21
				1898 ...	+ 1	...	- 9
				1899 ...	-27	...	-18
				1900 ...	- 1	...	+ 2
				1901 ...	-10	...	+ 7
				1902 ...	- 5	...	+10

These figures show that the eastern half of South Africa had heavier rain than usual during the same period (1892-4) as India, that it was steadily in defect during the first five years of the period of persistent deficiency of rain in India, and was especially deficient in the years 1897 and 1899, the former being the year and rainfall season following the first severe drought year of the period in India, and the latter the same year as that of the greatest drought experienced in India during the past 100 years at least. The parallelism between the two sets of figures is, indeed, more complete than I anticipated, and hence I consider not only that Mr. Sutton's conclusion to the effect that "there is nothing to justify the statement that South Africa has been under the same influence as that which set up the prolonged drought in Australia and the dry years in India" is neither in accordance with what I hold to be the general meteorological conditions and relations of the whole Indo-oceanic area nor even with the data which Mr. Sutton furnishes. The probability, so far as I can judge, is at least twenty to one that there is some relation such as I have suggested. The chief object of my address was, I may add, to urge the necessity for the coordination and inter-comparison of the meteorological observations of the whole Indo-oceanic area and their discussion as a whole by an efficient scientific staff in London. The question at issue between Mr. Sutton and myself, for example, could be authoritatively settled by such an investigating office.

In conclusion, I hope that my remarks may not be interpreted as in any way depreciating the value of Mr. Sutton's work in collecting and discussing as a whole the rainfall data of South Africa, and in utilising the data to obtain normal means for purposes of comparison. His work will, I am confident, be appreciated by all interested in African meteorology from any point of view.

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